High-Resolution Microimaging of a Rabbit Larynx: Toward the Development of a Three-Dimensional Computational Model of Phonotrauma

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INTRODUCTION

- Phonotrauma results in disruption of the epithelial barrier and eventual development of benign vocal fold lesions (e.g., nodules, polyps).
- Vocal folds are vulnerable to several significant biomechanical stresses (e.g., impact, longitudinal, shear) during vibration.
- Because lesions frequently occur at the middle one-third portion of vocal folds, impact stress may be greatest in this region.

Our laboratory has developed a magnetic resonance imaging (MRI) model to allow for the investigation of phonotrauma. This model provides a more accurate computational model of vocal fold vibration based on precise phonatory parameters (e.g., vocal intensity, airflow).

Overarching goal of research program: To quantify biomechanical stresses during phonotrauma and validate observations of molecular and tissue structure.

STUDY PURPOSE

- Magnetic resonance (MR) imaging has proven useful in generating high-quality images of the larynx and distinguishing soft tissues.
- Purpose: To obtain high-quality MR images of rabbit larynges to acquire details of morphology and layered structure of vocal folds.

METHODS

- Vanderbilt University Institutional Animal Care and Use Committee approved animal protocol.
- Male New Zealand white breeder rabbits weighing 3.2-4.0 kg. Anesthetized via intramuscular injections.
- Monitored general wellbeing and state of anesthesia.

IN VIVO Phonation Procedures

- Midline incision exposed larynx and trachea.
- Tracheostomy created to provide stable airway.
- 3.5-cm endotracheal tube inserted 2 cm below glottal opening. Continuous humidified airflow delivered through glottis at 144 cm/min heated at 37°C.
- Thyroid and cricoid cartilages sutured together.
- 3 trials of phonation elicited to obtain:
  - Acoustic measures (vocal intensity and fundamental frequency)
  - Aerodynamic measures
  - High-speed imaging

- Sutures between thyroid and cricoid cartilages remained in place to maintain adducted position.
- Animals were sacrificed and larynges were harvested.

Scanning Procedures

- Excised laryngeal specimens secured in 12 mL syringe with Fomblin 06:6 perfluoropolyether (Solvay Solexis, Thornford, NJ).
- Specimens placed in 38-mm inner diameter radionucleography coil.
- Scanning sequences performed using a Varian 9.4 Tesla horizontal bore imaging system (Varian Inc., Palo Alto, CA).
- Obtained multislice images in axial, coronal, and sagittal imaging planes.
- Data reconstructed using Matlab 2012a (Mathworks Inc., Natick, MA) using inverse Fourier transform.

RESULTS

- MR Scan 1: Fixed tissue using magnetization T2-weighted scanning (11 hours)
  - Overall resolution of 80 microns.
  - Evidence of contrast between structures, although minimal.
  - Substantial tissue deformation after specimen fixation with approximately 0.5 mm glottal gap.

- MR Scan 2: Fixed tissue using T1-weighted scanning (13 hours)
  - Smoother contour of vocal fold edges and improved representation of laryngeal shape.
  - Less defined contrast between larynx proper vs. vocalis muscle.
  - Large improvement in resolution of 55 microns.

- MR Scan 3: Fresh tissue using T2-weighted scanning (3 hours)
  - Less effective resolution of 110 microns.
  - Less contrast between structures.
  - Better preservation of the natural geometry of the laryngeal structures.

- MR Scan 4: Fresh tissue using magnetization T2-weighted scanning (2.5 hours)
  - Resolution of 125 microns.
  - Excellent contrast and pronounced distinction between lamina propria vs. vocalis muscle.

- MR Scan 5: Fresh tissue using magnetization T2-weighted scanning (12 hours)
  - Continued excellent contrast.
  - Substantial improvement in image resolution of 67 microns.
  - Minimal appreciable tissue deformation.

- MR Scan 6: Fixed tissue using magnetization T2-weighted scanning (12 hours)
  - Substantial improvement in image resolution of 67 microns.
  - Less appreciable contrast as compared to Scan 6.
  - Slight tissue deformation after formalin fixation with mild glottal gap.

CONCLUSIONS

- Overall Image Resolution
  - Best resolution (55 microns) acquired using faster relaxation time with a T1-weighted scanning sequence (MR scan 2).

- Preservation of Tissue Geometry
  - Freshly excised tissue resulted in minimal tissue deformation.

BEST MR Scan

- Of six MR scans, best scanning sequence was a special magnetization T2-weighted scan with fresh laryngeal tissue (MR scan & Figure 3).
- Most ideal balance between overall resolution, contrast, and minimal tissue deformation.

STUDY QUESTIONS

- How do changes in imaging parameters affect overall resolution?
- What is the impact of tissue temperature on image quality?

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REFERENCES